Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 196 (2022) 348–355

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020

A graph based recommender system for managing Covid-19 Crisis

Yemna Sayeb*, Marwa Jebri, Henda Ben Ghezala

RIADI, National School of Computer Sciences, Manouba University, Tunisia

Abstract

The paper aims to present a graph based recommender system for managing the Covid-19 crisis by considering patient and medical staff data. Working with limited number of medical staff, require optimization when creating the appropriate medical staff to assist patient. Patient medical files usually contain more information about the patient diseases and symptoms. In this paper the recommender system at first analyses the patient medical files to find and decide which profile of medical staff could assist efficiency this patient in a crisis situation. Second the recommender system by taking into account the availability of the medical staff will try to propose others doctors with the same profile and the nearest competencies.

Peer-review under responsibility of the scientific committee of the CENTERIS –International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2021

Keywords: recommender system, Covid-19 crisis, graph model

1. Introduction

Coronavirus has spread all over the world and brought significant impact to everyday life. During such sudden crisis a health care responsible must jump into action quickly, and see the different profile and competency of the

* Corresponding author.
E-mail address: yemna.Sayeb@ensi-uma.tn

Peer-review under responsibility of the scientific committee of the CENTERIS –International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2021
10.1016/j.procs.2021.12.023

health care worker to identify easily the appropriate health worker who can assist efficiency [1]. So we can infer the need to using a system which focused on recommending relevant information.
Recommender systems are automated systems that, in a personalized and meaningful way, lead users to relevant items for them in a wide space of options [2]. They attempt to recommend the most suitable items (products or services) to particular users (individuals or businesses) by predicting a user's interest in an item based on related information about the items, the users and the interactions between items and users [3].
A recommender system includes usually three steps; Acquiring preference from customers input data, computing the recommendation using proper techniques and finally presenting the recommendations results [4]. They can be defined as "software tools and techniques providing suggestions for items to be of use to a user" [5]. Most of their practical applications are e-commerce, e-learning, e-library, e-government and e-business services [6]. However, Recommender systems are used for different purposes it is not limited for those field. Therefore, the study demonstrated that recommender systems have already been explored in health services as Health Care Recommender for educational, dietary and activity assistance purposes [7][8], and for specific field of medicine domain related to cancer disease by using a user-based collaborative filtering approach [2]

For our proposed approach, we used a recommender system based on graph model in covid-19 crisis for managing health care staff to be able to establish the appropriate health care team able to assist the patient. We propose to align patient information data with health care staff data and give recommendation to facilitate the identification of the appropriate health worker even if he is in distant place. To reach our objective we use the patient files which usually contain more information about the patient diseases and symptoms. In this paper the recommender system at first analyses the patient files to find and decide which profile of medical staff could assist efficiency this patient in a crisis situation. Second the recommender system by taking into account the availability of the medical staff will try to propose others doctors with the same profiles and the nearest competencies.

This paper is then organized in three sections besides the introduction and the conclusion. The first section describes the related works of the recommender systems especially those used in health care domain. The second section presents the proposed solution and the third section presents some results obtained using the Neo4J data base system which is a graph oriented data base system [29].

2. Related Works

2.1. Recommender System in Health Care Information System

Health care recommender system is a tool that helps in decision making process specifically in healthcare services. It reduces information overload in services and makes great signification to the information.
There are typically two target users for a health recommender system, [9] systems for health care professionals as end-users, in which recommender systems are typically used to improve information access either for a specific case, clinical guidelines or research article, and systems for patients as end-users, in which recommender system provides high quality health care information in an intelligible way or alternative procedures for illnesses, fitness or nutrition.
Besides, health care recommender systems help to improve information access where in [10] authors tried to identify health care social networks relevant for a patient. Also are used to help with diagnosis [11] by providing fuzzy pictures clustering and recommendation for possible illness, thus improving diagnostic accuracy. Then [12] aid patient by recommending clinical examination to enhance early diagnostics. Therapies come next, where in [13] author have been used recommender system to prevent side effects and interaction of medication. And finally recommender systems were used in health behaviour recommendation to suggest walking routes [14], and running routes [15].

Other like Yogatheesan Varatharajah et al. [16] inspired by covid-19 crisis proposes Recommender System based on Human-in-the-loop which is able to provide an estimate of the patient's probability of experiencing serious complications (such as requiring mechanical ventilation or death) using the patient's baseline characteristics. Based on this prognosis, a decision algorithm would recommend admission or discharge home and if admitted, the level of medical care required (e.g., general ward, step down unit, intensive care unit).

In order to retrieve the information effectively, there are fundamentally three types of filtering [5]:

Collaborative Filtering	Content-based Filtering	Hybrid Filtering
It is based on the knowledge collected and composed from users.	It is based on the knowledge aggregated from the users and unit descriptions of historical data.	It is a combination of different approaches and techniques basically combining Collaborative Filtering and Content-based Filtering.

2.2. Graph model in recommender system

To address the needs of comprehensive representation and to support flexible recommendation approaches, the graph model has the capability to represent different types of data inputs and to support different recommendation, approaches using various techniques. While Graphs are a powerful abstraction that provides a structural representation of the relationships among various users and/or items, they can be constructed on the users, on the items, or on both. [23]. In [24], authors apply graphs with the Artificial Neural Network ANN in predicting the number of covid-19 confirmed cases and deaths and also for the future seven days. The trained neural networks were then used to predict the number of confirmed cases and the number of deaths for the future seven day in Brazil, Portugal and United States. Recommender systems face numerous challenges because of data sparsity. Users often specify only a small number of ratings. As a result, a pair of users may often have specified only a small number of ratings. Such situations can be addressed effectively with the use of both dimensionality reduction and graph-based models [23].

There have been many graph-based approaches for recommender systems. Therefore, in all these approaches the items (or content) to recommend appear as nodes in the graph. For example, [24] introduced a directed graph of users in recommender systems, where the directed edges correspond to the notion of predictability. Based on this graph, personalized recommendations can be generated via a few reasonably short (strongly predictable) directed paths joining multiple users. [25] also proposed a graph-theoretic model for collaborative filtering, in which items and users are both represented as nodes and the edges represent the recommendation data set (interaction between user and items). A social network graph of users is then created based on the original graph, and recommendations are generated by navigating the combination of the original graph and user social network graph.

2.3. Actor, competence and performance in health care services before COVID-19 Crisis

In our proposed approach, we hope to recommend the appropriate health care medical staff even when some member of this staff is enable to be in the health care services where we need him. In fact there are many reasons for the absence of the doctor during the covid-19 crisis situation. It may be because of their illness or the rate of their occupations and that's why we try to use the recommender system the find the medical staff with the some profile or the nearest competencies to replace those absents whatever their reasons.

In the table below we remember the definition the three important concepts which will be considered in our recommender system. It is about the actor, the competence and the performance

Actor	Competence	Performance
Organizational unit with expressible and collective knowledge [17] An actor has competences that reflect the implementation of his knowledge in an operational context and assigned to a role within a business process. The actor should use its expertise for the conduct of activities belonging	The competence concept covers three levels [18]: • Unit competence which is considered as the basic level, it is tightly linked to an activity. • Individual competence which is the set of unit competences and resources developed/required by an actor within the framework of assigned activities.	The performance concept refers to the achievements, in quality and quantity, of an individual or group work. Employees are critical components of business success and their performances directly influence company performance [20].

to his role [18][19].	• Collective competences which is considered as the highest competence level and linked to processes and group of actors.	

In this paper, the actor is the doctor or the nurse who are in contact with the patient to treat him. We try to record from the beginning for each patient, all medical staff that treats him. Second we try to record all the competencies of these actors. Then in a crisis situation, the recommender system will help us to find the appropriate medical staff based on required and acquired competence in order to assign the right actor to the right activity by identifying the available competence [21]. This helps to stress on competence importance into performance assessment. The assessment should take into account the competence level of a candidate when performing the corresponding task. This assignment ensures a performance level that should be maintained after any changes. Several researches were made focusing on the development of key competencies and terminal objectives for training of all healthcare workers in disaster preparedness [22]. A competency-based approach was proposed for healthcare worker disaster preparedness and response training [22]

3. Proposed Approach

Our contribution aims to improve and manage patient data through the parient files and medical staff's competencies within a recommender system which can lead to significant improvements at the operational level. Our approach aims to improve the ability of recommender system to respond to new requirements quickly and effectively by providing a clear definition of desired acts, identifying the impacted component and measuring the actor performance. Recommender method depends mainly on doctor and nurse profiles, patient data and information about the disponibility of the medical staff in a Covid-19 crisis situation. The proposed approach is a graph based recommender system to support managing COVID-19 crisis.

3.1. Research method

In this paper, we try to propose a recommender system for the SMART2C RRV Tunisian project (Research Results' Valorization project). The project is about developing a smart system for a COVID-19 Crisis Committee based on a relational database. We choose to adopt a graph model which seems to be the appropriate model for recommender system. In a first stage we will use a test dataset, and if the results are interesting and the research method is validated by the project committee, we will move to the real dataset of the project.

The recommender system is proposed for managing the Covid-19 crisis by considering patient and medical staff data and it works in a heterogeneous and multi-relational directed graph. The graph is formed taking as nodes, Patient, Doctor, Nurse, Patient_Medical_File and Doctor_Competencies; and as edges the interrelations between them.

3.2. Graph construction

The graph is build through Cypher scripts of nodes, and edges.

```
// Person Label and it's Nodes
CREATE (p:Person {  Name :  'Person 1', BirthDate : '1980-03-10', Gender : 'Male'});;
```

```
MATCH
  (p:Person),
  (d:Doctor)
WHERE p.Name = 'Person 1' AND d.Name = 'Doctor 1'
```

```
CREATE (p)-[i:Is]->(d)
RETURN type(i);
```

Each Cypher query will be optimized and transformed into an execution plan by the Cypher query planner. And it is possible to re-use Cypher queries instead of having to parse and build new execution plans. The figure 1 shows the graph result obtained using NEO4J as graph data base system [29]. As shown we observe all the patients related to the medical staffs that take care of them. Every doctor is related to the medical files of his patients.

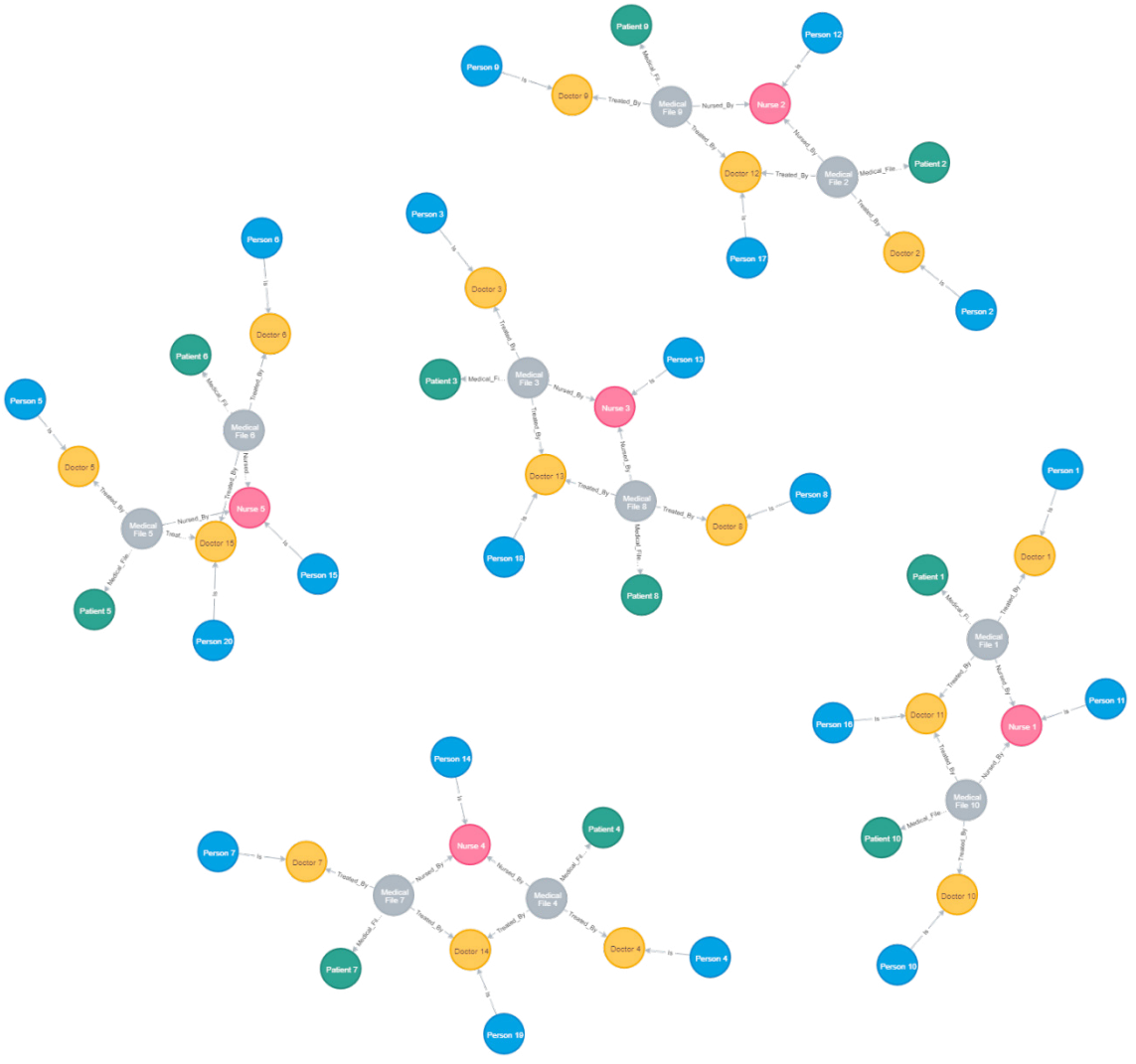


Fig. 1. The graph visualization using Neo4J

3.3. Graph Result:

Usually, the Neo4j Graph Algorithms are used to compute metrics for graphs, nodes, or relationships. They can provide insights on relevant entities in the graph (centralities, ranking), or inherent structures like communities (community-detection, graph-partitioning, clustering). In this paper, Neo4J algorithm is used for ordering entities already known to the target actor or recommending new ones, it is crucial to take his or her context into account. The context is “any information that can be used to characterize the situation of any entity”, an entity being a person,

place or object relevant to the user's interaction with the application [27].
In our case, the context is related to a crisis situation of a patient and how to be more efficient to assist this patient and to rescue him rapidly. It is about founding the right members of health care staff in this critical situation that can handle this situation at that time. But usually in Covid-19 crisis situation, it is not possible to find the appropriate medical staff that could take care efficiency the patient because of many reasons: unavailability, work vacation, disease, work shift. In figure 2, we try to make apparent the doctors who take care of patients with their specialty. Our objective is to improve the result obtained in figure 2 by using the graph based recommender system and through analyzing the patient medical files, we can propose the right doctor who can help efficiency in a crisis situation.

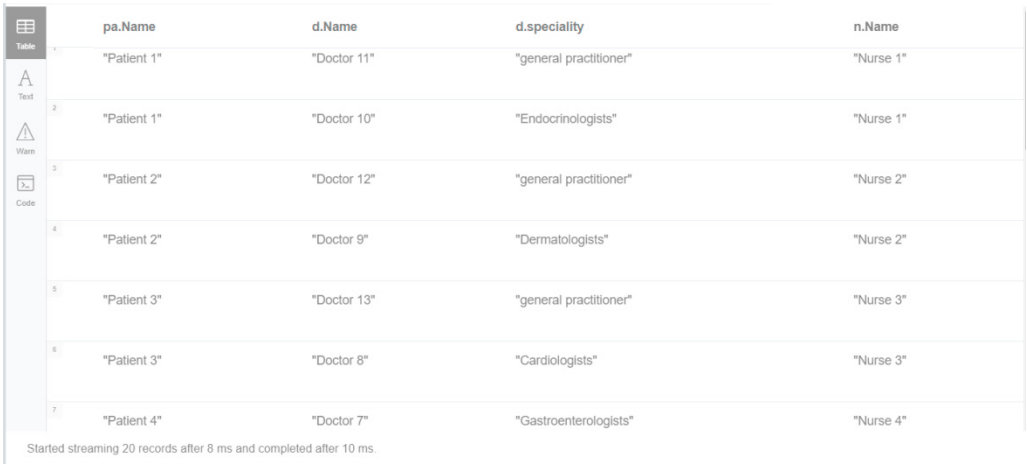


Fig. 2. List of the patients and the medical staff taking care of them

3.4. Recommendation System algorithm

Once the graph is formed and the context defined, a ranking algorithm has to be applied [28]. The graph model through the Neo4j system gives us a list of health care staff and with the recommender algorithm we will enrich this list with the appropriate medical staff. This algorithm must give us the final list of matching doctor with their competence and their availability in that period of crisis situation. The recommender system at first analyses the patient medical files to find and decide which profile of medical staff could assist efficiency this patient in a crisis situation as shown in figure 3. This figure shows the doctor_5 as recommended doctor added to the two others doctors: doctor_11 and doctor_10 to the patient_1as this patient has cardiological problem.

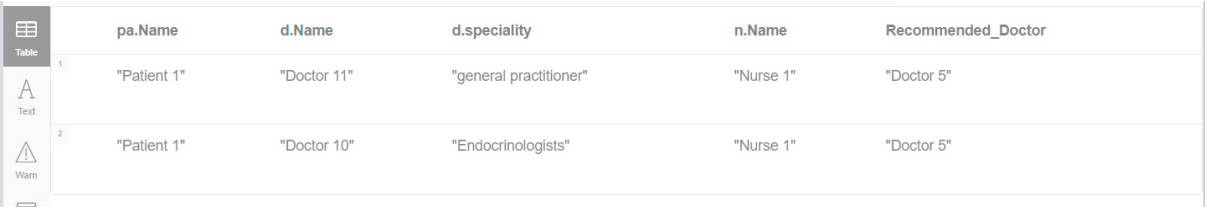
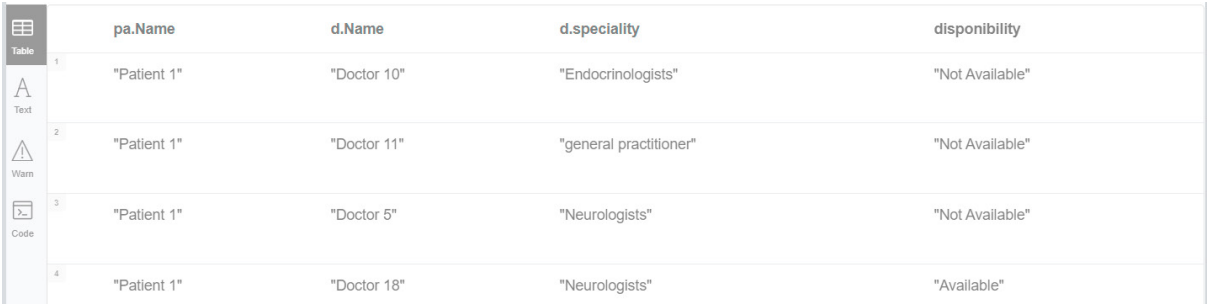


Fig. 3. Result of the graph recommender system considering the patient medical file

In a second time, the recommender system by taking into account the availability of the medical staff as shown in

figure 4 will try to propose others doctors with the same profile and the nearest competencies.



	pa.Name	d.Name	d.speciality	disponibility
1	"Patient 1"	"Doctor 10"	"Endocrinologists"	"Not Available"
2	"Patient 1"	"Doctor 11"	"general practitioner"	"Not Available"
3	"Patient 1"	"Doctor 5"	"Neurologists"	"Not Available"
4	"Patient 1"	"Doctor 18"	"Neurologists"	"Available"

Fig. 4 Result of the graph recommender system considering the doctor availability

4. Conclusion and future work

Recommender system embrace a wide set of solutions, each of which has its own advantages and limitations. A synthesis of the use of graph in recommender system is however available on this paper. The system then aims to predict the suitable doctor to assist the relevant patient.

In this paper, we propose a recommender system taking advantage of a graph model. In such, information is stored as nodes, which are linked together by edges. This allows to easily retrieving knowledge about relationships between nodes.

Besides, there sometimes is need to use doctor competence in order to retrieve efficient suggestions. Depending on the purpose of the recommender system, simply proposing the doctor who has adequate competence may do the job. At this end and as a future work we aim to extend our work by taking into account the C3HIS Ontology [1] of health care medical staff into the graph recommender system.

Acknowledgement

I want to acknowledge a list of students who still works over this project : Molka EL Jazi, Ben Omrane Omar, Meher Kharbachi and Asma Smaoui, Hamza Bessaoud from tunisians universities.

References

[1] Yemna Sayeb, Marwa Jebri, Henda Ben Ghezala, Managing COVID-19 Crisis using C3HIS Ontology, 2020, CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020

[2] Liliana Brandãoa, Fernando Paulo Belfoa, Alexandre Silvaa, Wavelet-based cancer drug recommender system, 2020, CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020

[3] J. Bobadilla, F. Ortega, A. Hernando, A. Gutiérrez, Recommender systems survey, Knowledge-Based Systems, 46 (2013) 109-132.

[4] Kangning Wei, Jinghua Huang, Shaohong Fu, 2007, A Survey of E-Commerce Recommender Systems, 1-4244-0885-7/07/$20.00 ©2007 IEEE.

[5] Francesco Ricci, Lior Rokach and Bracha Shapira, Introduction to Recommender Systems Handbook. Springer, 2011.

[6] Jie Lu, Dianshuang Wu, Mingsong Mao, Wei Wang, Guangquan Zhang, Recommender System Application Developments: A Survey

[7] J. Kim, J. Lee, J. Park and Y. Lee, “Design of Diet Recommendation System for Healthcare Service Based on User Information”, Fourth International Conference on Computer Sciences and Convergence Information Technology, ICCIT '09, pp.516-518, 24-26 Nov 2009.

[8] M. Wiesner, “Adapting recommender systems to the requirements of personal health record systems”, Proceedings of ACM International Health Informatics Syposium, pp. 410-414, 11-12 November 2010.

[9] Wiesner, M., & Pfeifer, D. (2014). Health recommender systems: concepts,requirements, technical basics and challenges. International journal of environmental research and public health, 11 , 2580–2607.

[10] Song and Marsh (Song, I., & Marsh, N. V. (2012). Anonymous indexing of health conditions for a similarity measure. IEEE Transactions on Information Technology in 1090 Biomedicine, 16 , 737–744).

[11] Thong, N. T., & Son, L. H. (2015). HIFCF: An effective hybrid model between picture fuzzy clustering and intuitionistic fuzzy recommender systems for medical diagnosis. Expert Systems with Applications, 42 , 3682–3701.

[12] Pattaraintakorn, P., Zaverucha, G. M., & Cercone, N. (2007). Web based health 1050 recommender system using rough sets, survival analysis and rule-based expert systems. In International Workshop on Rough Sets, Fuzzy Sets, Data Mining, and Granular-Soft Computing (pp. 491–499). Springer.

[13] Pinto, D., Costa, P., Camacho, R., & Costa, V. S. (2015). Predicting drugs adverse side-effects using a recommender-system. In International Conference 1055 on Discovery Science (pp. 201–208). Springer.

[14] Sasaki, W., & Takama, Y. (2013). Walking route recommender system considering saw criteria. In Technologies and Applications of Artificial Intelligence 1085 (TAAI), 2013 Conference on (pp. 246–251). IEEE.

[15] Issa, H., Guirguis, A., Beshara, S., Agne, S., & Dengel, A. (2016). Preference based filtering and recommendations for running routes. In T. Majchrzak,965 P. Traverso, V. Monfort, & K. Krempels (Eds.), Proc. of the 12th Int. Conf.on Web Information Systems and Technology, Vol. 2 (WEBIST) (pp. 139–146). doi:{10.5220/0005897801390146}.

[16] Yogatheesan Varatharajah , Andrew Trotter , Haotian Chen , Ravishankar Iyer A Dynamic Human-in-the-loop Recommender System for Evidence-based Clinical Staging of COVID-19 , HealthRecSys'20, September 26, 2020, Online, Worldwide

[17] Marwen Jabloun, Yemna Sayeb, Henda Ben Ghezala, and Khaled Gaaloul (2015) "Supporting Enterprise Changes Using Actor Performance Assessment" Springer International Publishing Switzerland 2015

[18] G. Pépio, N. Cheikhrouhou, M. Furbringer, and R. Glardon. (2006) UECML: Unified Enterprise Competence Modeling Languagel, Ecole Polytechnique Fédérale de Lausanne,

[19] M.Bennour and D. Crestani. (2006) Using competencies in performance estimation: From the ac-tivity to the process, Universite´ Montpellier 2,

[20] Ho, L.A. __What affects organizational performance? The linking of learning and knowledge management, (2008) Industrial Management + Data Systems.

[21] Marwen Jabloun, Yemna Sayeb, and Henda Ben ghezala (2013) "Enterprise Ontology Oriented Competence: a support for Enterprise Architecture", IEEE

[22] Edbert B Hsu, Tamara L Thomas, Eric B Bass, Dianne Whyne, Gabor D Kelen and Gary B Green (2006) "Healthcare worker competencies for disaster training" BMC Medical Education 2006, 6:19 doi:10.1186/1472-6920-6-19

[23] Charu C. Aggarwal, "Recommender Systems" The Textbook, 2016,Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

[24] Leonardo Sestrem de Oliveiraa, Sarah Beatriz Gruetzmachera, João Paulo Teixeiraa, "COVID-19 Time Series Prediction" , CENTERIS - International Conference on Enterprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies

[25] Charu C. Aggarwal, Joel L. Wolf, Kun-Lung Wu, Philip S. Yu, KDD '99: Proceedings of the fifth ACM SIGKDD international conference on Knowledge discovery and data miningAugust 1999 Pages 201–212https://doi.org/10.1145/312129.312230

[26] Mirza, Batul J. (2001) ,Jumping Connections: A Graph-Theoretic Model for Recommender Systems

[27] Anind K. Dey, Understanding and Using Context, Personal Ubi Comp 5, 4–7 (2001). https://doi.org/10.1007/s007790170019

[28] El Helou, Christophe Salzmann, Stéphane Sire, Denis Gillet, (2009), The 3A contextual ranking system: simultaneously recommending actors, assets, and group activities

[29] Yemna Sayeb, Radhouane Ayari, Sarra Naceur, Henda Ben Ghezala (2017), "From Relational Database to Big Data: Converting Relational to Graph Database, MOOC Database as Example" , J. Ubiquitous Syst. Pervasive Networks 8(2): 15-20.